NARI

Adaptive Back Sheet Material for Acoustic Liner Application

Carl H. Gerhold and Michael G. Jones
Liner Technology Facility
NASA Langley Research Center

Dawnielle Farrar
Johns Hopkins University Applied Physics Laboratory

NASA Aeronautics Research Mission Directorate (ARMD)
FY12 Seedling Phase I Technical Seminar
July 9-11, 2013

Outline

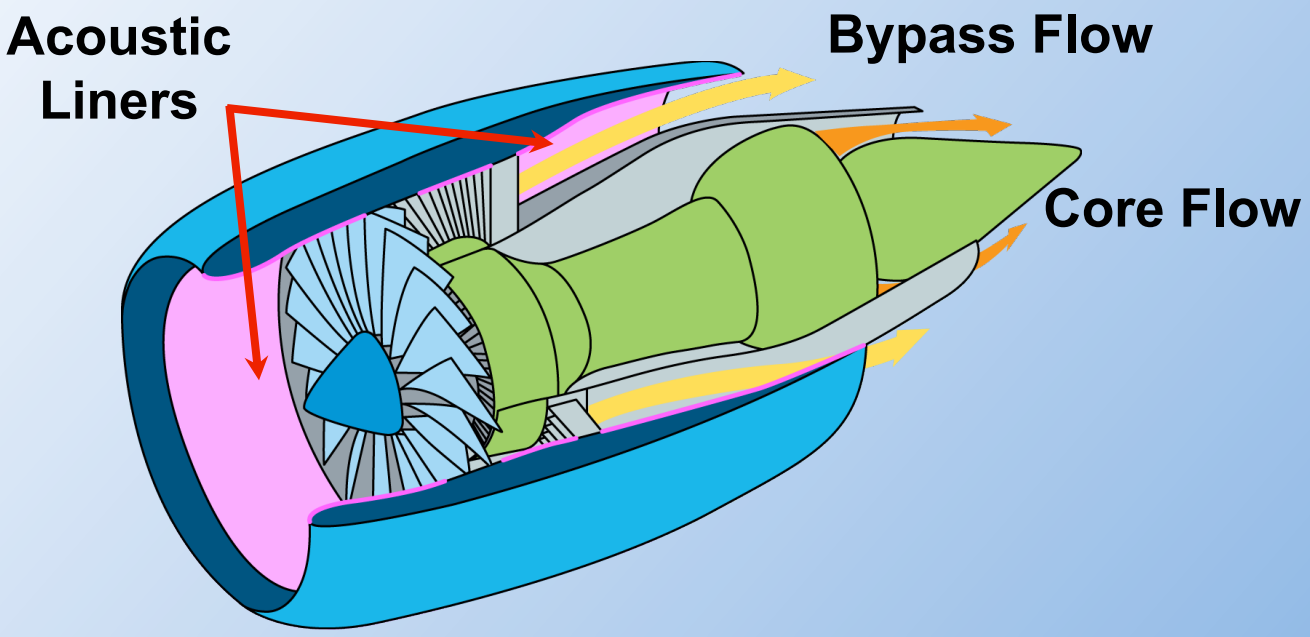
NARI

- Background
- Description of Piezo-electric Composite
- Results to Date
  - Mechanical
  - Acoustic
  - Lessons Learned
- Summary and Conclusions
- Next Steps

The Challenge

NARI

Aircraft Engine Nacelle

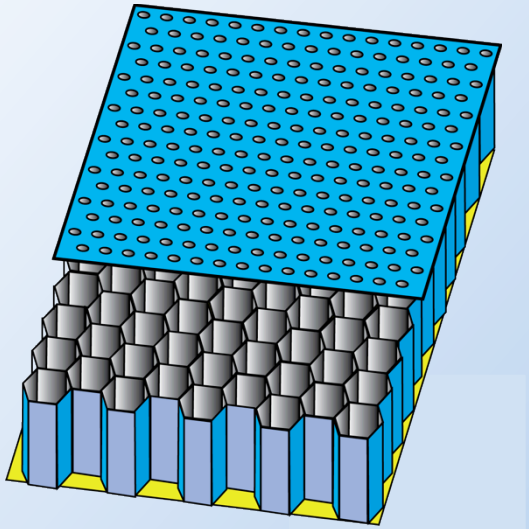


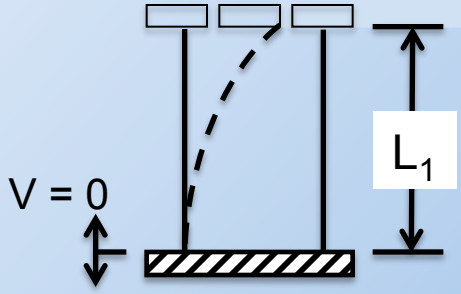
- Engine size increases
- Frequency of source decreases
- Nacelle treatment area decreases

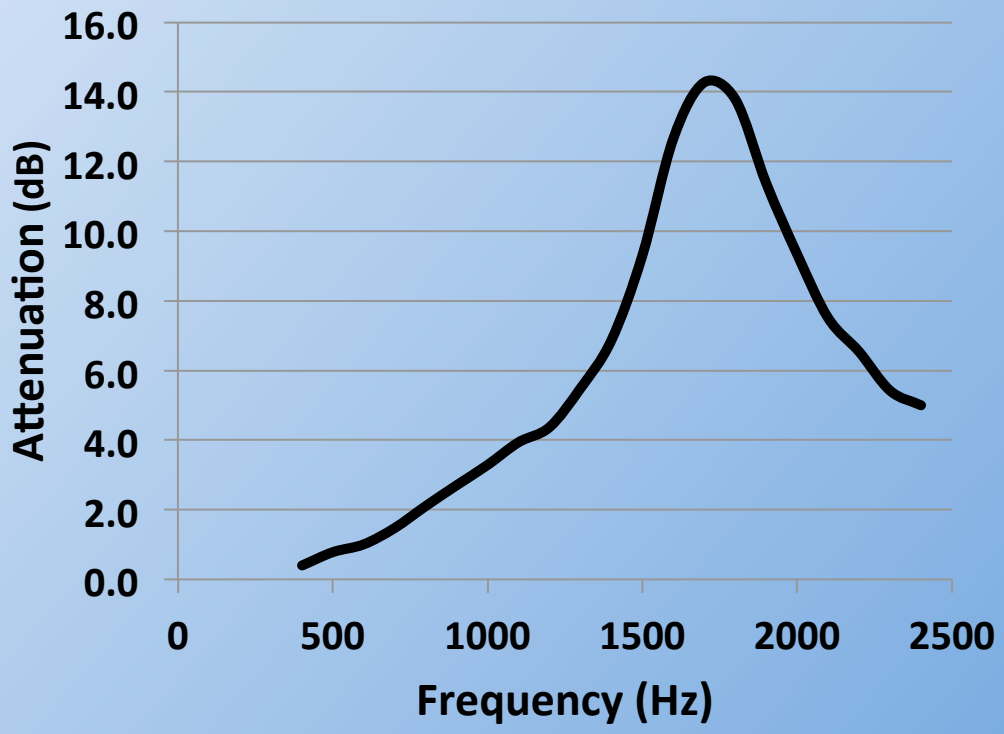
=> Need to get more performance out of less acoustic liner

SDOF Liner - Solid Back Plane

NARI



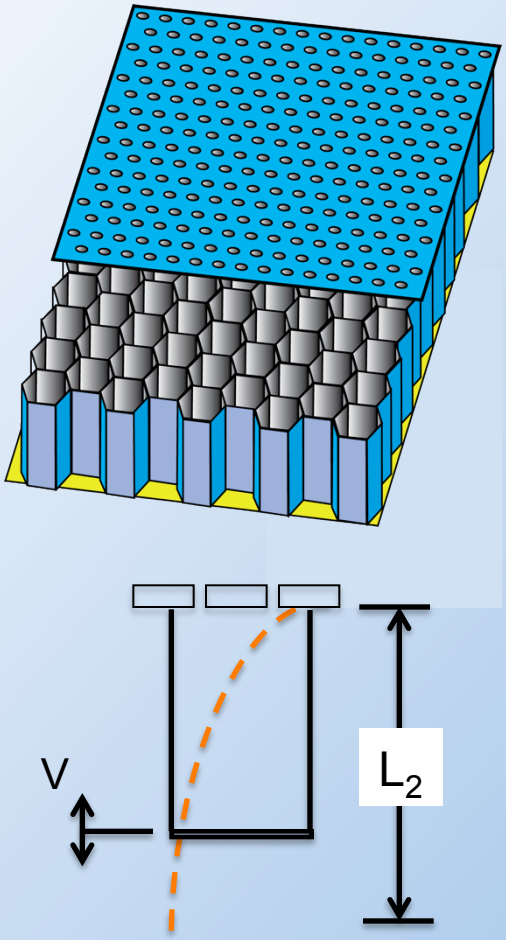


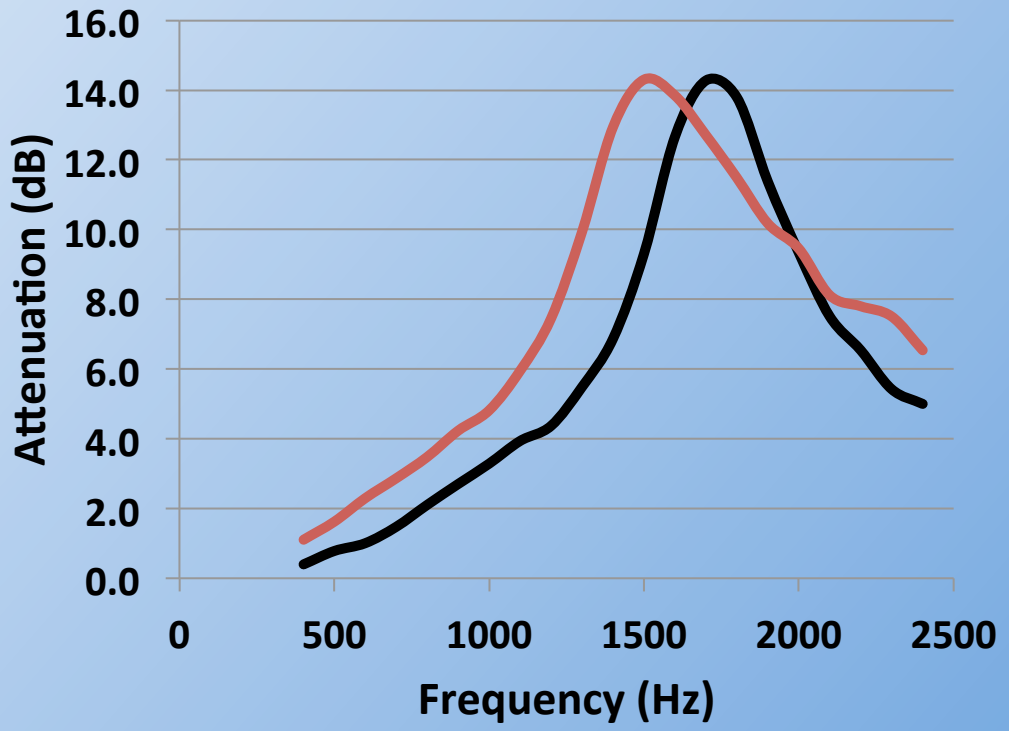


⇒ Frequency of peak attenuation fixed by L_1

Proposed Liner with Compliant Back Plane

NARI





=> Compliant back plane can expand frequency range of attenuation

Objectives of Research

NARI

- Build samples coupons with piezo-electric material
- Determine acoustic and mechanical properties
- Estimate effect of material on liner attenuation

Candidate Material

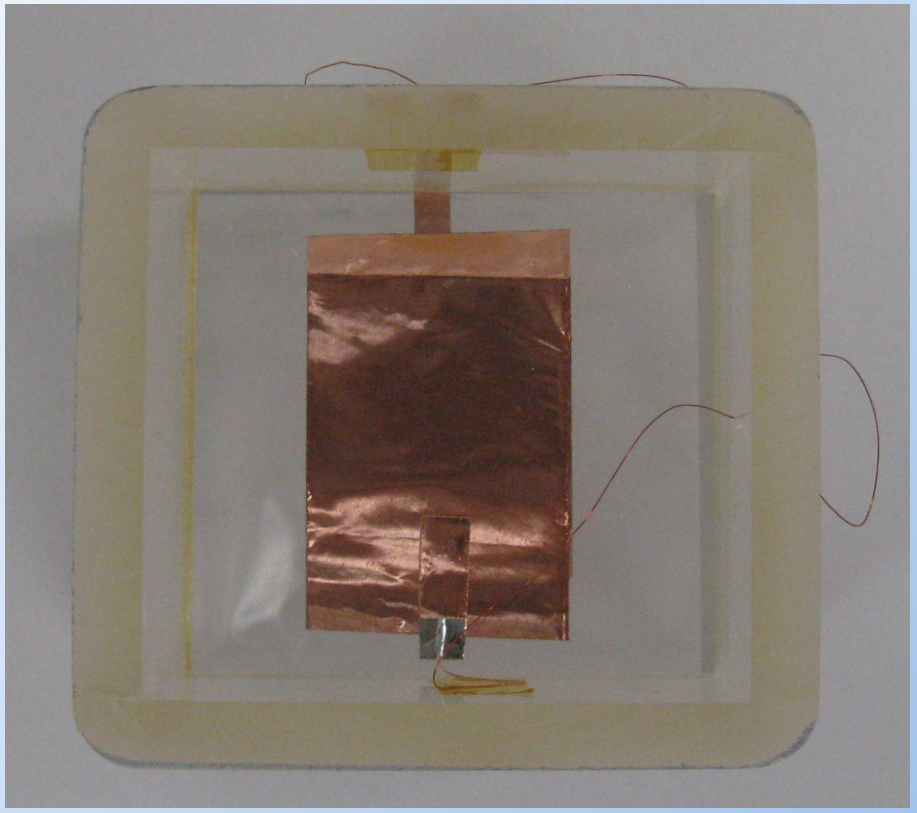
NARI

- PBLG Piezoelectric Composite Film
  - Composed of an α-helical polypeptide
  - Produced via corona charging to pre-align macroscopic dipoles along helical axis
  - Responds to external force (sensor)
  - Responds to electric field (actuator)
  - Responds at acoustic frequencies
- Developed at Johns Hopkins University Applied Physics Laboratory

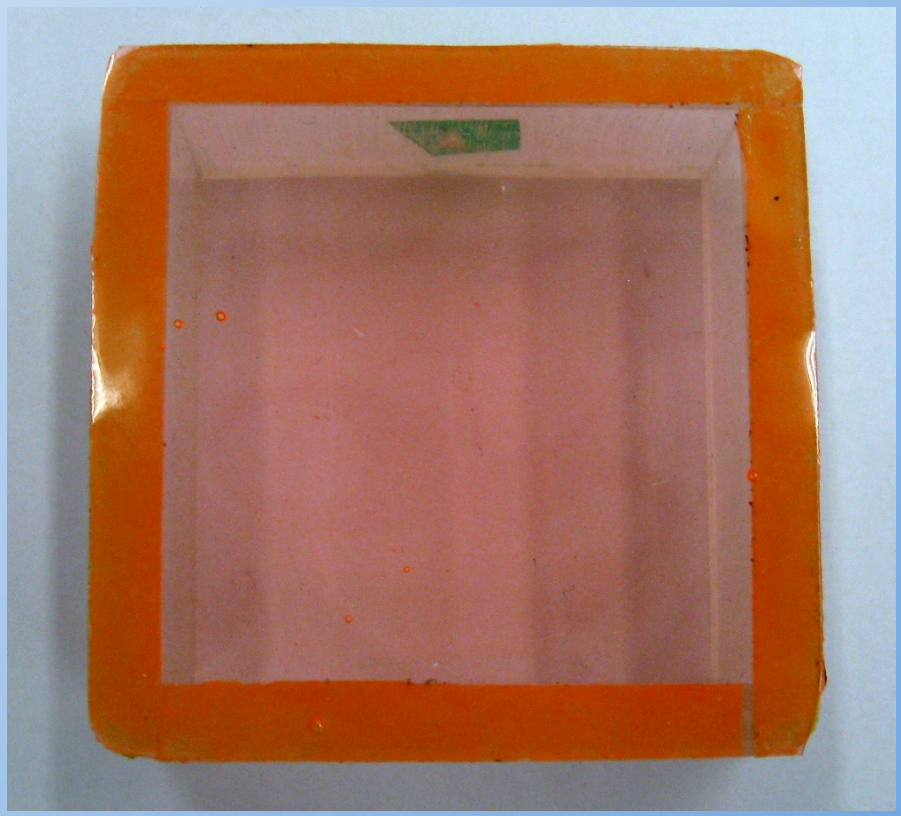
Sample Coupons

NARI

Unencapsulated sample with electrode



Encapsulated sample (without electrode)



Samples Evaluated

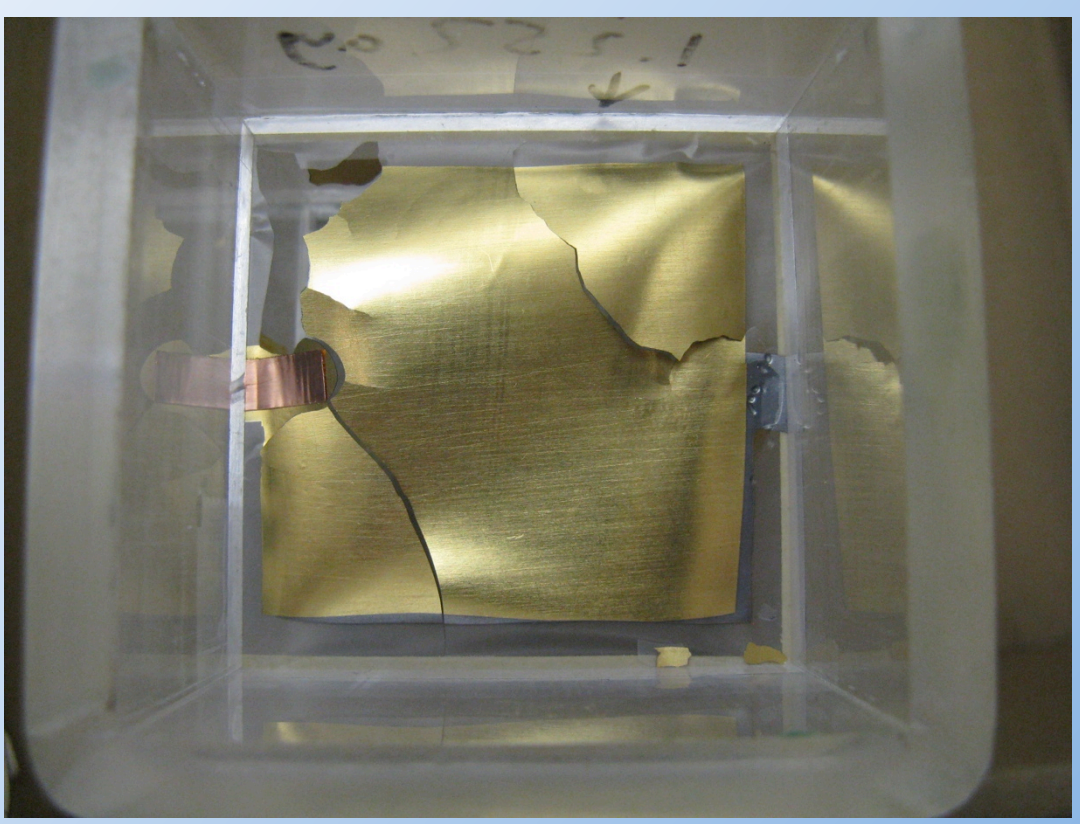
NARI

Sample	Description	Electrode	Electrode size	Status
JHS1	Composite film, no encapsulate	Cr-Au, evaporated	1”x1”	Functional
JHS2	Composite film, no encapsulate	Cr-Au, evaporated	1.75”x1.75”	Destroyed
JHS3	Composite film, encapsulated	No electrode	Na	Functional
JHS4	Composite film, no encapsulate	Conductive adhesive	1.75”x1.00”	Destroyed
JHS5	Composite film, encapsulted	No electrode	Na	Functional

Table 1: Cumulative list of samples received and the status from evaluating both standard un-encapsulated and encapsulated film samples.

Sample JHS2 after Failure

NARI

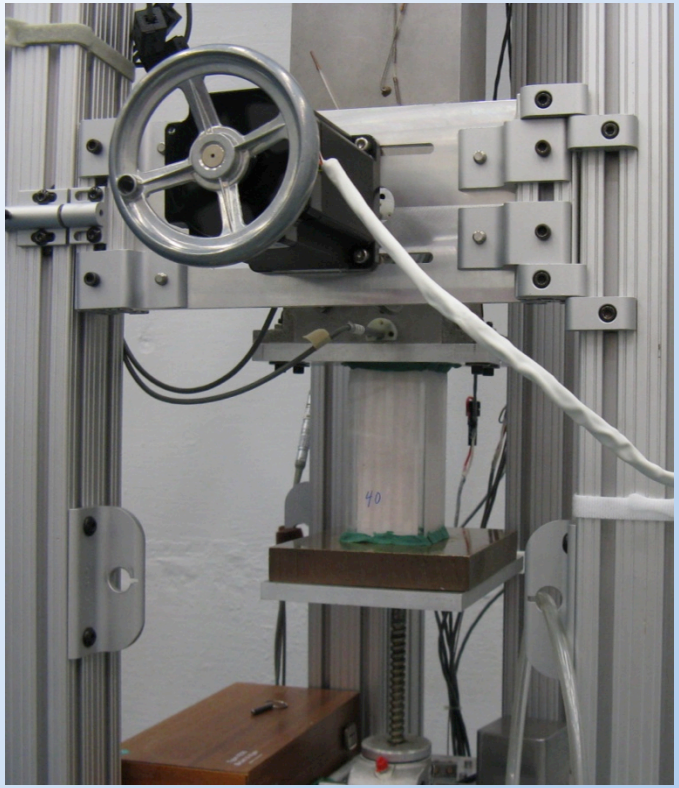


=> The un-encapsulated film was re-designed to offer samples with greater robustness

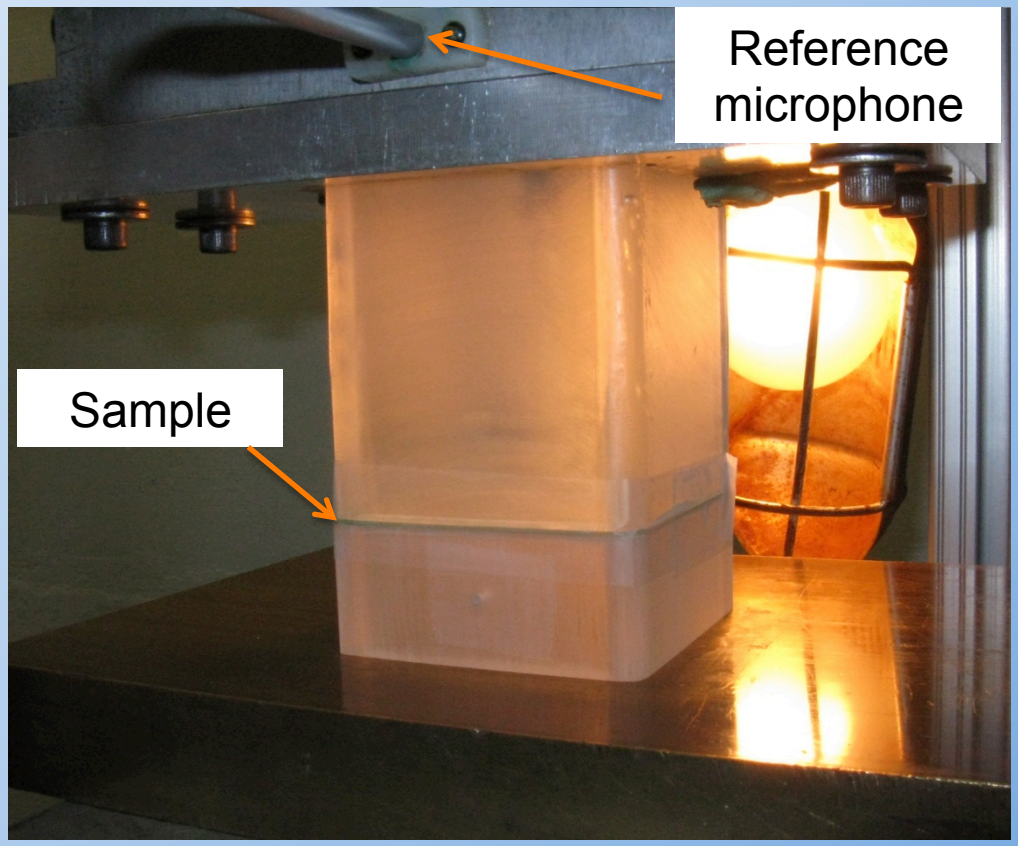
Evaluate Properties

- Acoustic Properties
  - Measure acoustic impedance
  - Measure impedance change with voltage excitation
- Mechanical Properties
  - Measure velocity response to voltage excitation
  - Measure velocity response to acoustic excitation

Set-up for Normal Impedance Testing



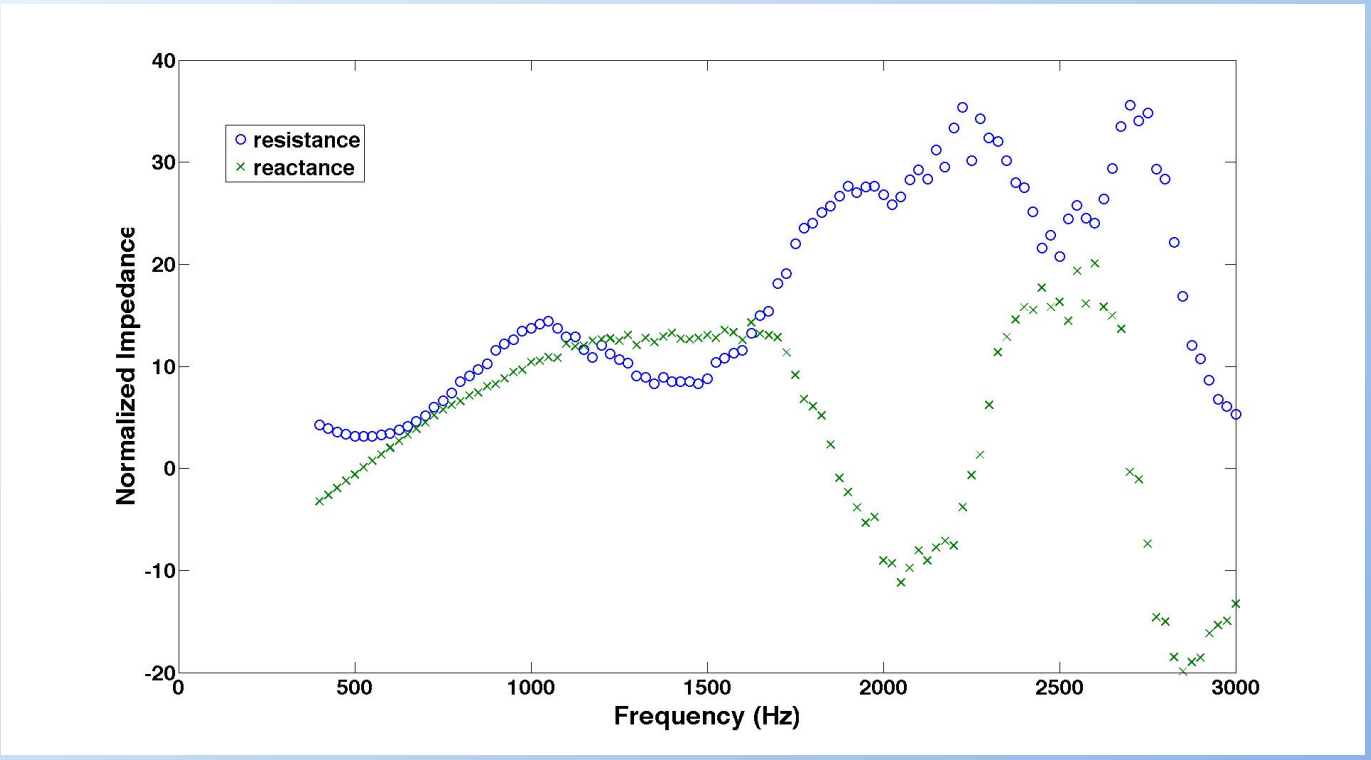
Normal Incidence Tube



Piezo-electric sample in NIT

Typical Impedance Measurement

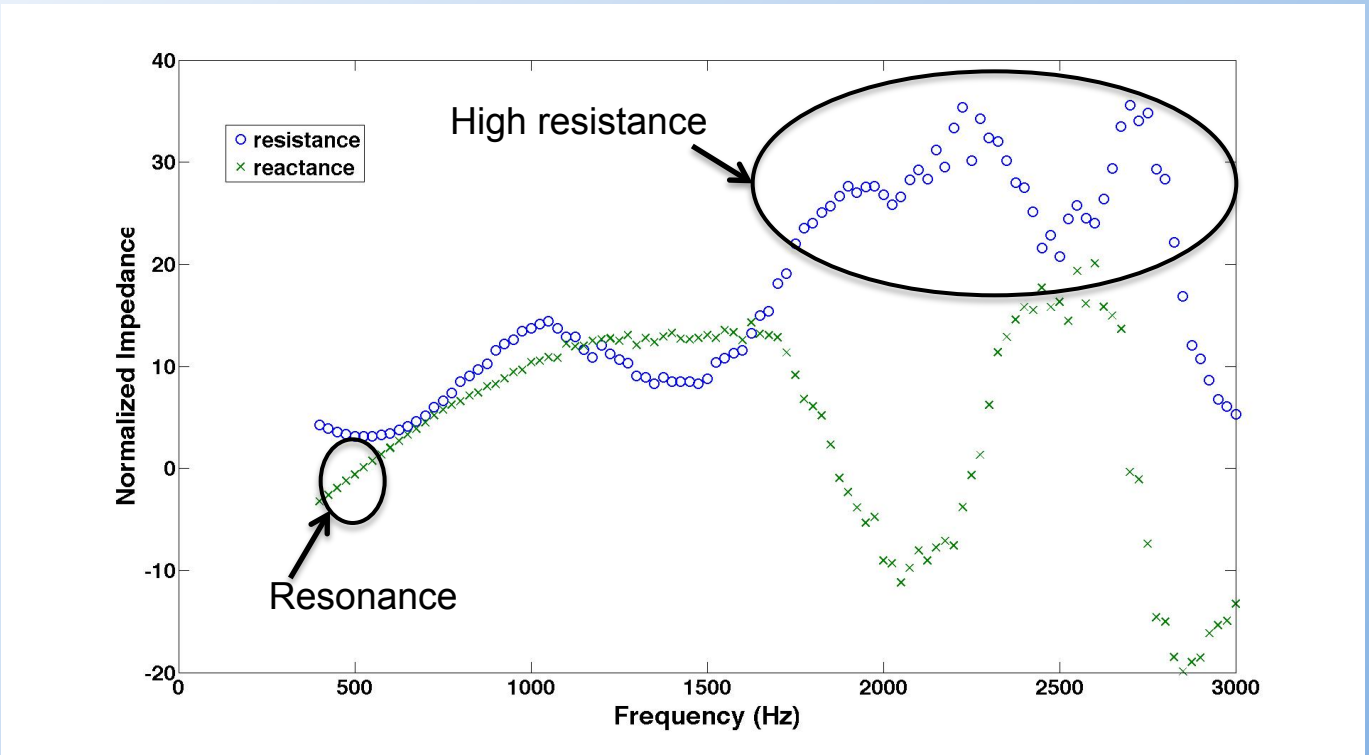
NARI



Impedance results from test set-up with encapsulated sample JHS3 evaluated with two-microphone method using broadband noise at 130 dB overall sound level.

Typical Impedance Measurement

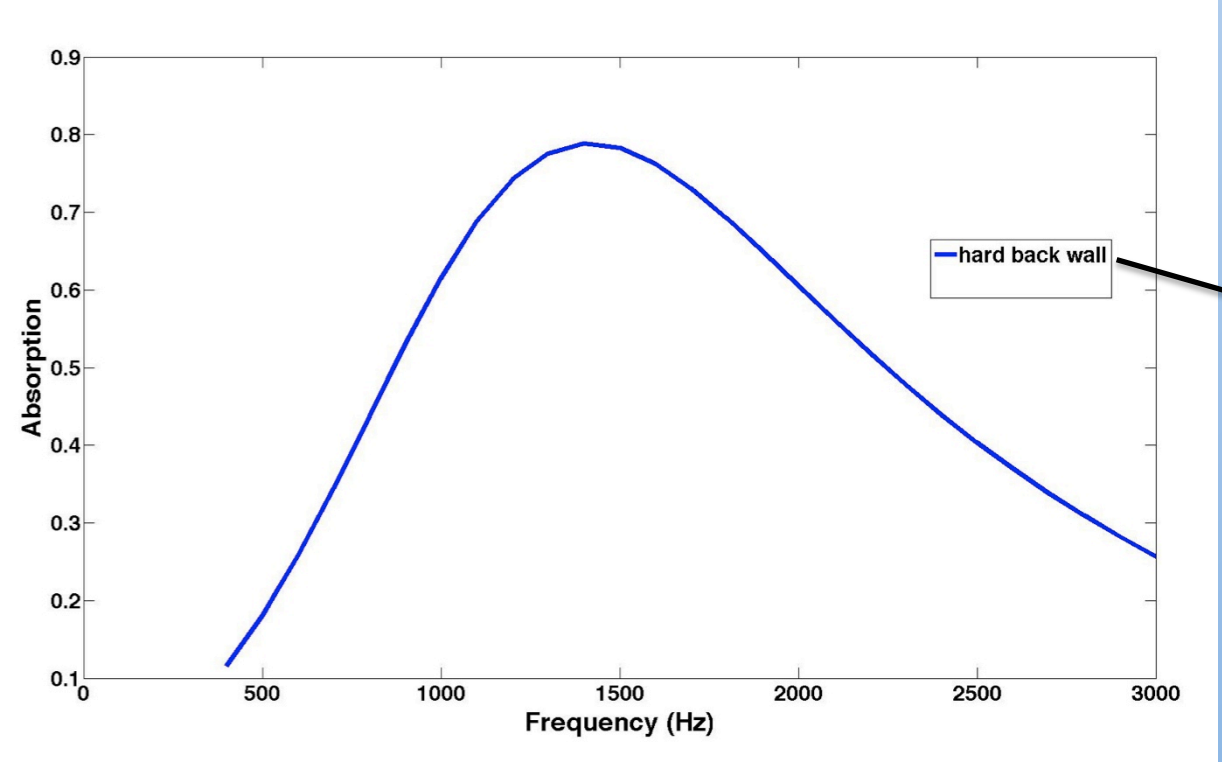
NARI

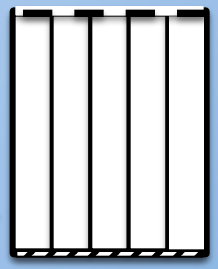


Impedance results from test set-up with encapsulated sample JHS3 evaluated with two-microphone method using broadband noise at 130 dB overall sound level.

Application of Passive Compliant Back Wall

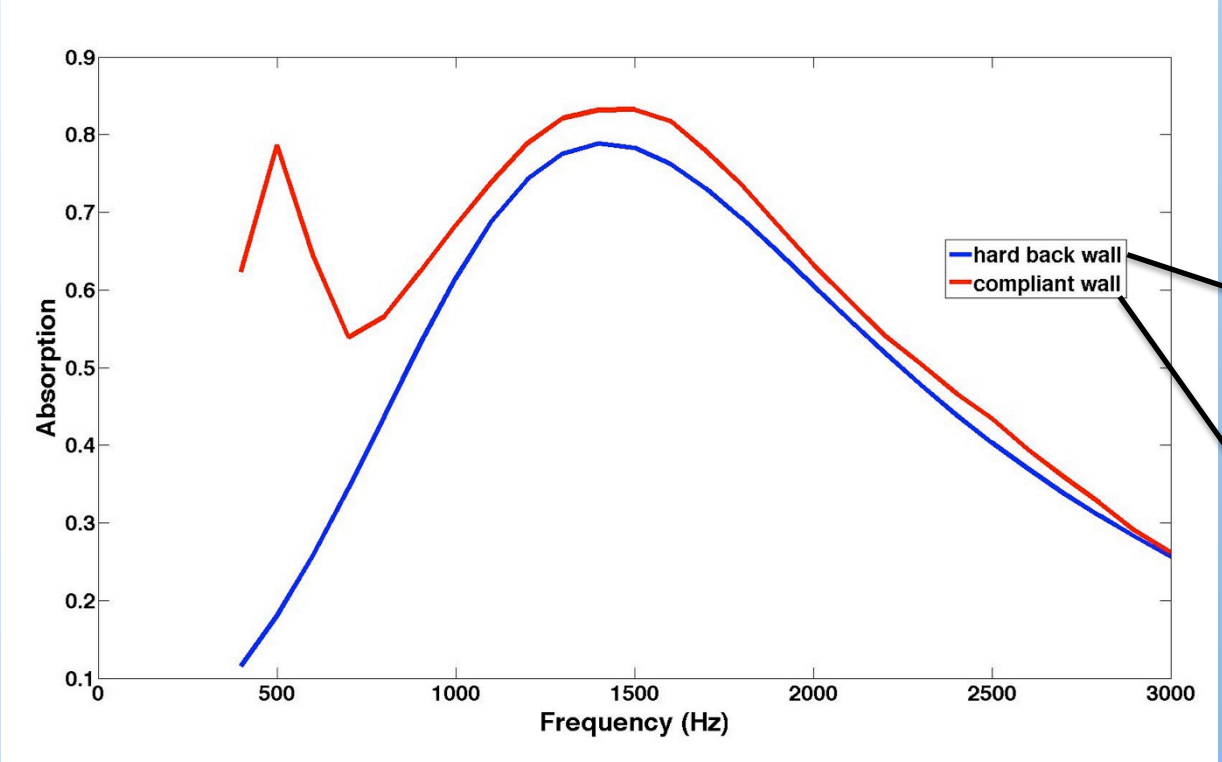
NARI





Calculated absorption of a perforate-over-honeycomb liner (core 1.50 in) compares rigid back wall to compliant back wall, JHS3.

Application of Passive Compliant Back Wall

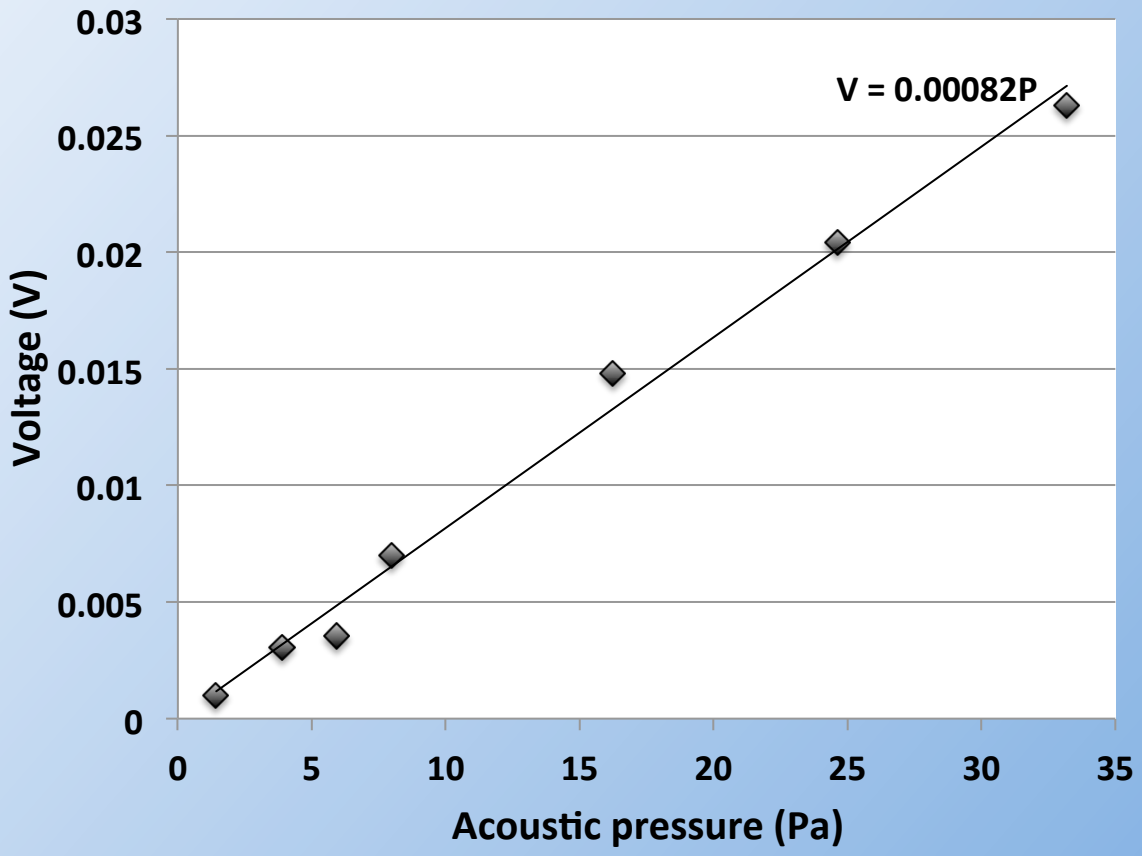


Calculated absorption of a perforate-over-honeycomb liner (core 1.50 in) compares rigid back wall to compliant back wall, JHS3.

=> Compliant back wall adds to liner absorption

Piezoelectric Film as Sensor

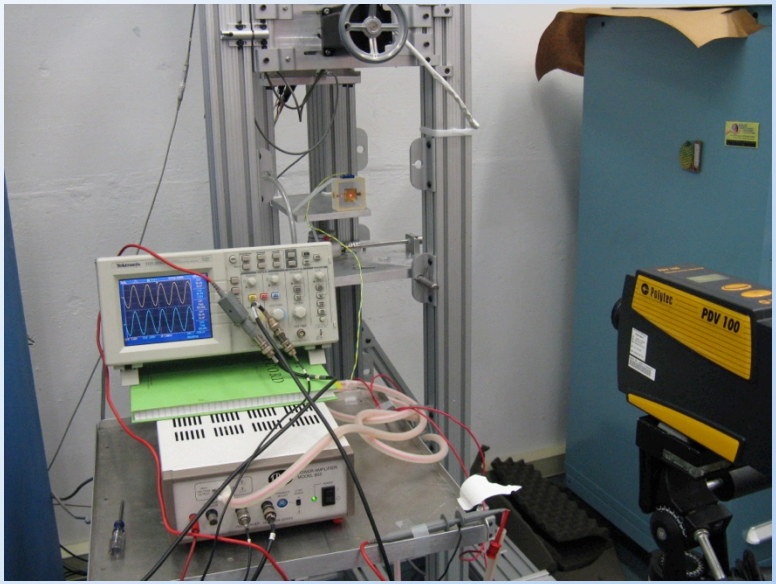
NARI



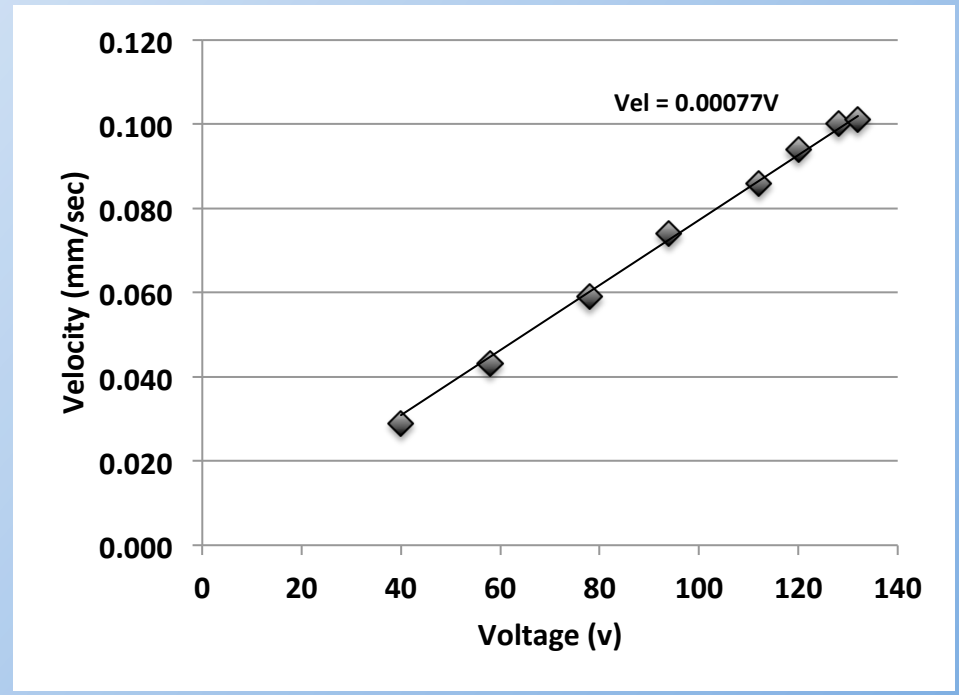
Voltage from electrode of sample JHS1 with acoustic excitation at 1000 Hz

Piezoelectric Film as Actuator

NARI



Test set up for velocity measurement

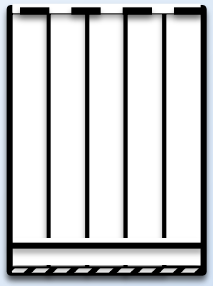


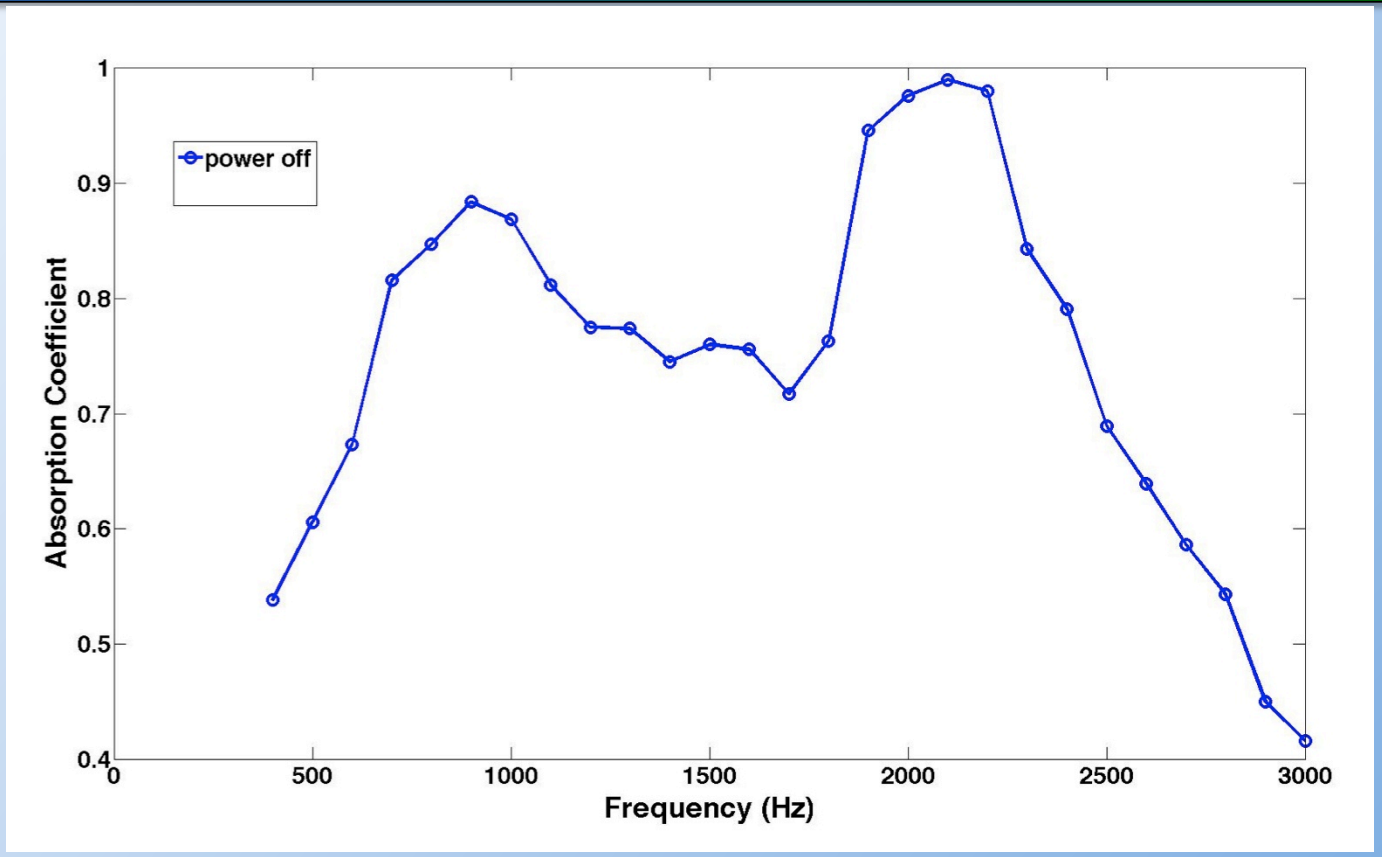
Measured velocity of sample JHS1 with voltage excitation at 1500 Hz

=> Velocity response much less than expected acoustic particle velocity

Application of Active Compliant Back Wall

NARI

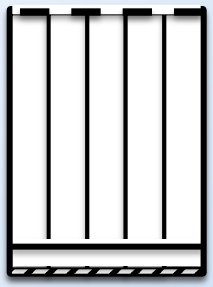


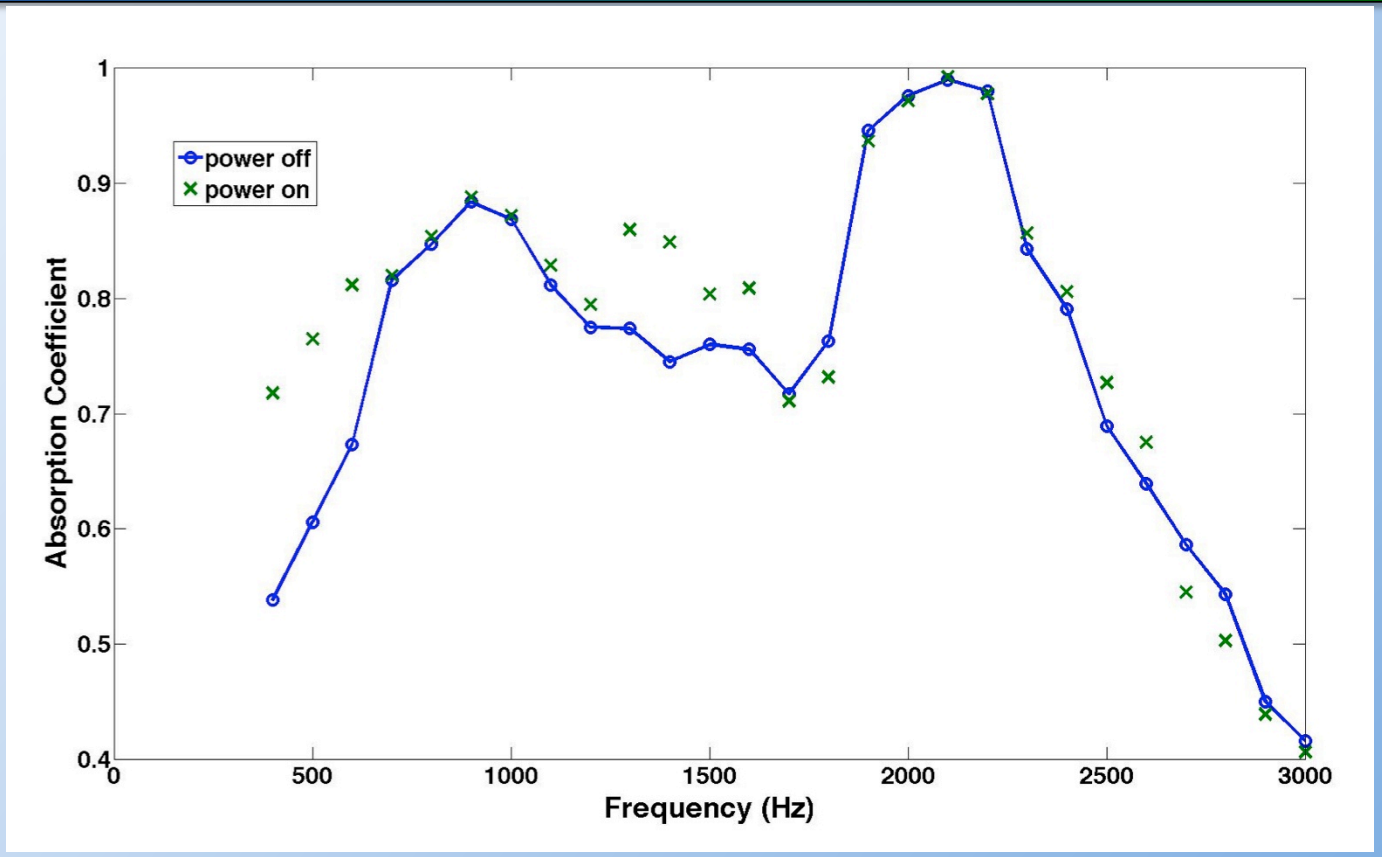


Calculated absorption coefficient of liner (core 1.5 in) with JHS1 backwall, compares power off to power on, 150 volt excitation

Application of Active Compliant Back Wall

NARI





Calculated absorption coefficient of liner (core 1.5 in) with JHS1 backwall, compares power off to power on, 150 volt excitation

=> Despite low authority, measurable change in liner absorption is indicated

Conclusions (Part 1 of 2)

NARI

- Developed liner samples for evaluation
  - Improved design to provide suitable robustness
- Developed experiments to evaluate the piezoelectric film samples
  - Measured mechanical properties
  - Measured acoustic properties

Conclusions (Part 2 of 2)

NARI

- Demonstrated that energizing the piezo-electric changes normal impedance in a controlled way
  - Current design lacks authority to alter impedance significantly.
- Developed mathematical model of liner absorption including compliant back wall
  - Model is semi-empirical

Next Steps – Phase I

NARI

- Incorporate piezoelectric into honeycomb structure
  - 2 in x 2 in sample for NIT
  - Estimate absorption of composite structure
  - Measure absorption to validate prediction
- Begin re-design of electrodes for greater authority
- Present results to date at Acoustics Technical Working Group
  - April 2013
  - October 2013

Next Steps – Phase II

- Improve electrode design
  - Increased authority
  - Incorporate in honeycomb structure
- Improve mathematical model of compliant wall effect
- Design, fabricate, and test active wall liner for Grazing Flow Impedance Tube
  - 2 inch x 24 inch liner sample size
  - Flow speed up to Mach 0.500
  - Tone and broadband sound input

Thank You

NARI

Adaptive Back Sheet Material for Acoustic Liner Application